

A Review on Heat Transfer from Different Shaped Fins

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Abstract- Heat sinks with fins are generally used to enhance the heat transfer rate in many industrial applications such as cooling of electronic, power electronic, telecommunication and automotive components. In many situations where heat transfer is by natural convection fins offer economical and trouble free solutions. The weight and volume of the equipment are the most important parameters of design. Now days the general trend is to use compact systems especially in electronic field which leads to higher packing density of systems causing higher heat generation. It affects the performance of system and may cause the system failure. The most preferred method for cooling electronic and telecommunications devices is passive cooling since it is cost effective and reliable solution. It doesn't require costly enhancing devices. This features leads to focus on development of efficient fin heat sink. The important element that defines the geometry of the heat sink is its fins. The fins generally used in industry are straight, circular and pin shaped. The objective of this work is review on the heat transfer rate by different shaped fins in different systems. The proper selection of the interruption length increases the heat transfer rate and in addition providing fin interruptions results in considerable weight reduction that can lead to lower manufacturing cost.

Index Terms— Fines, convection, Heat transfer rate, Thermal conductivity, Conduction.

I. INTRODUCTION

The heat transfer through the heat sinks present in flow channel can be increased by employing modification in passive surfaces, such as extended surfaces with geometrical modifications. These techniques are having wide application such as cooling turbine aerofoil, electronic cooling systems, biomedical instruments, and heat exchangers. The pin fin technology is widely used in many applications such as computer mother board heat sink over microprocessor. In this study the pin fin is under consideration for enhancement of heat transfer rate.

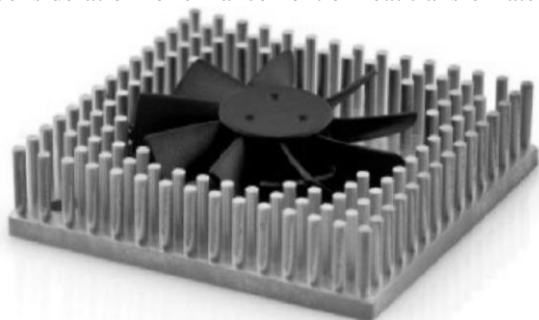


Figure 1: Heat exchanger used in INTEL microprocessor in computer

The heat transfer can be enhanced by following methods

- I. Indirect techniques
- II. Direct techniques

1.1. Indirect techniques

The passive technique mainly deals with surface modification by altering its geometries in flow passage to enhance the heat transfer by incorporating the inserts or fins. This modification alters the flow pattern over the geometry of surface to achieve maximum possible pressure drop for enhancing the heat transfer rate. The passive techniques do not require any external power to enhance the heat transfer rate as of active techniques. The passive technique the extended surfaces are used to increase the heat transfer rate maintain maximum possible pressure gradient across the flow channel.

The extended surface mainly retards the flow rate of the fluid in channel and alters the flow pattern that

ultimately leads to enhanced heat transfer rate. The direct techniques does not require any external agency to empower the heat transfer through the surface rather the surface alternation are done in various fashion such as geometrical modification, incorporating various inserts to alter the flow behavior that lead s to pressure drop across the channel for increasing the heat transfer. The following methods are employed for heat transfer by the means of indirect techniques:

- I. Surface treatment: the alternation is made in the surface finish of the walls of heat exchange r such as heat sink. The surface are treated chemically or coated with another material in order to improve the heat transfer. This method is widely employed for boiling and condensing purposes.
- II. Rough surface: these are the modification made on the surfaces to achieve turbulence in the flow near the surface of heat exchanger to improve heat transfer, without much increase in the surface area of contact between the fluid and the surface.
- III. Extended surface: the modified development is going in surface to increase the fluid and wall contact area. This is achieved by adding more material to the surfaces known as fins, for enhancing the heat transfer.
- IV. Displacement enhancement: for this method additional equipment are employed to increase the fluid flow rate over the surface in order to transport the heat energy from the heat exchanger surface at a rapid rate in order to enhance the heat transfer rate.
- V. Swirl flow devices: these devices are employed to produce superimposed swirl flow on the axial flow of the channel. This type swirl flow is achieved by attaching inlet with helical strip, screw type tube insert, or twisted tapes.
- VI. Coiled tube: this technique is used under space limitation, has compact size. The tube is arranged in helical coil shape. Due to its helical shape there is continuous change in the flow direction and increase in the flow friction near the wall, leading to higher pressure drop across the tube and hence the heat transfer coefficient increases.

1.2. Direct techniques

This technique is quit complicated as it requires external power input to achieve the desired modification in flow rate of fluid as well as the heat transfer rate. It is complicated to manufacture as well as design. It requires more space than indirect techniques due to various additional arrangements. As it require additional power so its implementation are limited.

This method can be implemented by any of the following methods:

- I. Mechanical aids: additional instruments are used for stir the fluid or rotating the surface. This method includes rotating tube heat exchangers and mass exchanger.
- II. Surface vibrations: this is employed to achieve higher heat transfer coefficient in single phase flow.
- III. Fluid vibration: this is perhaps the most practical type of vibration enhancement technique. It is used for single phase fluid.
- IV. Electrostatic fields: it is used in the heat exchanger involving di-electrical fluids. It can produce higher bulk mixing and induce forced convection or electro-magnetic pumping to increase the heat transfer in the heat exchanger.
- V. Injection: in this method the heat transfer is increased by injecting the same fluid or another fluid in the main stream of flow depending upon the application. This can be done through porous heat transfer interface or up-steaming the heat transfer section.
- VI. Suction: it is employed for the removal of vapour formed during the boiling through the porous heated interface in order to enhance the heat transfer. This method is employed to minimize the thermal resistance due formation of vapour near the heating surfaces.

II. LITERATURE REVIEW

Singh, B. Ubhi., et.al. [1], they have composed and broke down the warmth exchange through blade expansion in plate balances. They learned about different geometries, for example, rectangular, trapezium, triangular, and round expansions in plate balances. The outcomes demonstrated that plate blade with augmentations gave 5% to 13% more warmth exchange than balance without expansions. The adequacy of rectangular augmentation plate balance is more than alternate sorts of expansion.

S. R Pawar and R. B. Varasu [2], they have the warmth exchange by common convection from triangular scored blade exhibit. They learned about various indent geometries, for example, balance without score, blade with 20% indent with territory remuneration and balance with 40% indent with range pay as for different parameters, for example, tallness, length, score measurement, balance separating and balance thickness. The studies demonstrated that warmth exchange coefficient is lower in indented blade when contrasted with without score. There was 7% expansion in warmth exchange for 20% scored blade and 10% for 40% indent balance. The warmth exchange increments with expansion in indent size with territory remuneration.

U. S. Gawai, Mathew V. K. et.al. [3], they have done exploratory examination of warmth exchange by pin balance. The outcomes for single blade of aluminum and metal were concentrated on for warmth exchange. The outcomes demonstrated that the warmth exchange

coefficient and proficiency of aluminum balance was more prominent than the metal blade.

D. D. Palande and Walunj [4], they have done exploratory examination of grade thin plate blades heat sink under common convection. They have probed blades as for perspective proportion and distinctive radiator data wattage the outcome demonstrated that regular convection heat exchange increments with warmth information. The convective warmth exchange increments with viewpoint proportion.

Hagote and Dahake [5], they have improved the normal convection heat exchange coefficient by utilizing V-balance cluster. They dissected the V-balance utilizing ANSYS CFX and tentatively. They utilized plate blades where the balances were organized at a slant of 60°. The greatest convective warmth exchange got was 600.

V. Karthikeyan, Babu et.al. [6], they outlined and dissected the regular convection heat exchange coefficient between rectangular blade exhibit with expansion and balance cluster without augmentation. The warmth exchange through blade cluster with rectangular expansion, roundabout augmentation, trapezoidal expansion, triangular expansion, 18mm aperture, 20 mm puncturing, 22 mm aperture, 24 mm puncturing were 27.32, 25.63, 25.62, 24.68, 23.82, 23.52, 22.97, 22.63 separately. The blade exhibit with rectangular expansions has least temperature toward the end of balance cluster, when contrasted with balance exhibit with rectangular augmentation, without augmentation and with aperture.

M. Reddy and G. Shivashankaran [7], they have done numerical recreation of constrained convection heat exchange upgrade by permeable pin balance in rectangular channel. They had learned about round, long circular and short curved pin blade heat sink by changing gulf speeds i.e. 0.5m/s, 1m/s, 1.5m/s and 2m/s utilizing ANSYS CFD familiar programming. The outcome demonstrated that the warmth move efficiencies in permeable pin balance are around half higher than strong pin balance.

M. Ali, Tabassum et.al. [8], they have performed warm and water driven examination of rectangular balance exhibits with various aperture size and number. They have done analysis study by taking base range 1088 mm². They changed puncturing from 0 to 2, and differed aperture breadth structure 0mm to 3mm. The outcomes demonstrated that warmth exchange and weight drop expanded with expansion in Reynolds number for all balances. With trials it was found that with increasingly or bigger holes the proficiency and viability expanded, though the warm resistance and weight drop diminished.

K. Kumar, Vinay et.al. [9], they performed warm and auxiliary investigation of tree formed blade exhibit. They had brought tree formed blade with openings and tree molded balance without spaces for their

investigation. They additionally concentrated on the impact of material on the outcomes for the same geometries by taking aluminum composite, auxiliary steel and copper combination for the same. The outcomes got demonstrated that the abilities of the opened tree balances are superior to without opened tree blades. As indicated by material the copper blades with openings was best for warmth exchange among every one of the balances. The aluminum opened blade was discovered best as it has successful warmth exchange without distortion among every one of the balances taken for the study.

V. Kumar and Bartaria [10], they have done exploratory and CFD examination of a circular pin balance heat sink utilizing Ansys Fluent v.12.1. They have done the study by changing the measurement of curved pin blade i.e. by shifting the cross-segment territory. The outcomes demonstrated that for every one of the speeds 2mm minor pivot circular pin balance would be wise to warm resistance and weight drop.

K. Dhanawade and Sunnapwar et.al. [11], they have done the warm examination of square and roundabout punctured blade cluster by constrained convection. They have changed the span of aperture for the examination i.e. 10mm square, 8mm square, and 6mm square and for roundabout puncturing 10mm, 8mm, 6mm measurement. The outcome got demonstrated that the Nusselt numbers expanded with expansion in Reynolds number, warm contact expanded with expansion in puncturing and utilization of punctured balance build the warmth exchange furthermore there is diminishment in weight, sparing of material that at last declines the consumption on balance material.

P. Chaitanya and G. Rao [12], they have done the transient warm examination of drop molded pin blade cluster utilizing CFD. They have done the near study between round shape pin blade and drop molded pin balance. The outcomes demonstrated that the warmth exchange expanded because of expansion in contact surface zone in the middle of liquid and the balance. There was expansion in the weight drop for drop formed pin balances contrasted with roundabout pin balances.

H. Dange and Patil [13], they have done the trial and CFD investigation for warmth exchange on circular blade by constrained convection. They have done the investigation by changing the speed. The outcomes demonstrated that the warmth exchange coefficient increments with expansion in speed of liquid.

Junaidi, Ansari et.al. [14], they have done warm investigation of spread pin blade heat sink. They have done CFD examination utilizing ANSYS Fluent 12.1 with various point (i.e. 4 degree, 5 degree, 6 degree and 7 degree) of slant of pin blade as for base plate. The warmth exchange amid common convection is more in spread pin balance structure. The spread pin balance gives better air turbulence.

Dhumne and Farkade [15], they have done warmth exchange examination of tube shaped punctured blades in amazed course of action. The punctured balances of various sizes were utilized for the examination. The outcomes demonstrated that nusselt number increments with reduction in leeway proportion and entomb balance dividing. The erosion variable increments with diminishing in bury balance dispersing.

Mehran Ahandi et.al [16] researched numerically and tentatively relentless state normal convection heat exchange from vertically mounted inline interfered with blades. They have done 2D numerical reenactment to discover blade intrusion impacts by utilizing familiar programming. They built up a hand craft test bed to confirm hypothetical results. They performed complete trial and numerical parametric study to examine the impacts of blade dispersing and balance intrusions. The outcomes demonstrate that the interferences expanded the warmth exchange rate by resetting the warm and hydrodynamic limit layer. They machined and tried 12 heat sink tests for acceptance the present numerical study. It is demonstrated that the warmth flux from warmth sink expanded when interferences were included. They grew new minimized co connection to figure ideal blade interference for focused rectangular warmth sink.

A Ledezma et.al [17] contemplated the geometric advancement of a get together of stunned vertical plates that are introduced in altered volume they performed enhancement for dispersing, no of plates, plate measurement and lurch between segments. The extent utilized is $Pr=0.72$ and $103 \leq Ra \leq 106$ where Ra is Rayleigh number taking into account the vertical measurement of get together. They inferred that it is conceivable to enhance geometrically the inside reducing so as to engineer of a limited size volume the worldwide warm resistance.

Shivdas S kharche et.al [18] researched tentatively and hypothetically normal convection heat exchange from vertical rectangular blade clusters with and without scores at the middle. They examined the indents of various geometrical shapes. After the test study they have presumed that the warmth move rate in indent balances is more than the unnotched blades.

Wadhah Hussein et.al [19] led test study to examine heat exchange by regular convection in rectangular blade plates with roundabout apertures as warmth sinks. The example of the apertures included 24 round punctures for the primary blade, and the holes were expanded as 8 for every balance to 56 in fifth balance. They disseminated the holes in 6-14 lines and four segments. They watched that the temperature along the non-punctured blades was from 30 to 23.70 at lower force 6 W. They watched that the drop in temperature between the balance base and the tip expanded as the measurement of holes expanded. The

temperature drop at the most elevated force of 220 W was from 250 to 49 OC for non-punctured balances. They reasoned that the warmth exchange rate and the coefficient of warmth exchange expanded with expanded number of punctures.

M J sable et.al [20] concentrated on that the tall vertical balances limit the warmth exchange improvement as a result of limit layer advancement. They explored the warmth exchange upgrade procedure for common convection nearby vertical warmed plate with numerous V sort parcel plates in encompassing air encompassing. They observed that V molded parcel plates with go about as developed surface as well as stream tabulator. For warmth exchange upgrade they had connected angular allotment plates with edges confronted upstream to base plates. They watched that when the plate stature surpasses certain basic values the warmth move in downstream district of the allotment plate is upgraded due to the inflows of lower temperature liquid into the detachment locale. They watched that among the three distinctive blade cluster setups on vertical warmed plate, V sort balance exhibit plan performs superior to anything rectangular vertical balance cluster and V balance cluster with base dividing outline.

Mohamed Najib Bouaziz et al [21] aimed to quantify the effects of non-simplified situations on longitudinal fins efficiency. For this purpose a more realistic model, which had been developed based on variable profile and temperature-dependent thermo physical properties in transient twodimensional fin with internal non-uniform heat generation. An explicit exponential finite-difference method, conditionally stable, was extended in the study for the discretization of the governing equations. The numerical procedure consists in solving series of nodal temperature distribution according to the type of node, in order to reach the steady-state heat exchange. Then, the numerical simulation was used to present the sensitivity of some parameters on efficiency. Numerical results of interest were illustrated for a direct comparison with the traditional solutions. Extensive numerical experiments were conducted and showed that temperature-dependent heat transfer coefficient and generation lead to a significant reduction of fin efficiency. The simultaneous effects of parameters for this non-linear problem were not negligible.

Sasikumar and Balaji et al. [22] numerically studied a natural convection heat transfer and entropy generation from an array of vertical fins, standing on a horizontal duct, with turbulent fluid flow inside. The analysis was taken into account the variation of base temperature along the duct. One dimensional fin equation was solved using second order finite difference scheme.

Kundu and Das et al. [23] addressed With the help of the Frobenius expanding series the temperature

profiles of longitudinal fin, spine and annular fin had been determined analytically through a unified approach. Simplifying assumptions like length of arc idealization and insulated fin tip condition had been relaxed and a linear variation of the convective heat transfer coefficient along the fin surface had been taken into account. The thermal performance of all the three types of fin had been studied over a wide range of thermo-geometric parameters. It had been observed that the variable heat transfer coefficient had a strong influence over the fin efficiency. Finally, a generalized methodology had been pointed out for the optimum design of straight taper fins. A graphical representation of optimal fin parameters as a function of heat duty had also been provided.

Halder [24] et al. Fins alone contributed very small to the total heat transfer but they greatly influenced the heat transfer from the uncovered area of the cylinder. Among the various fin parameters, thickness had the greatest influence on heat transfer. For thin fins, there exists a fin length, which maximized the rate of heat transfer. The optimum number and dimensionless length of the fins were obtained as 6 and 0.2 respectively when fin thickness was 0.01.

Dibakar Rakshit and Balaji et al. [25] had investigated the conjugate convection from a finned channel with vertical rectangular fins being mounted on outside of the channel. The two dimensional governing equation, steady, incompressible, constant property laminar flow was solved for the fluid outside channel. For fluid flowing inside the channel, the flow was assumed to be turbulent with forced convection as the mode of heat transfer.

Haw-Long Lee et al [26] solved two dimensional inverse problem of estimating the unknown heat flux at a pin fin base by the conjugate gradient method. In estimating processes, no prior information on the functional form of the unknown quantity was required. The accuracy of the inverse analysis was examined by simulated exact and inexact measurements of temperature at interior locations of the pin fin. The numerical results showed that good estimations on the heat flux obtained for all the test cases. Furthermore such a technique was applied to determine the heat flux acting on an internal surface, where a direct measurement was not feasible.

Inmaculada Arauzo et al [27] addressed an elementary analytic procedure for the approximate solution of the quasi-one-dimensional heat conduction equation (a generalized Bessel equation) that governs the temperature variation in annular fins of hyperbolic profile. This fin shape was of remarkable importance because its heat transfer performance is close to that of the annular fin of convex parabolic profile, the so-called optimal annular fin that is capable of delivering maximum heat transfer for a given volume of material. The salient feature of the analytic procedure developed here was that for realistic combinations of

the two parameters: the enlarged Biot number and the normalized radii ratio, the truncated power series solutions embracing a moderate number of terms yields unprecedented results of excellent quality. The analytic results were conveniently presented in terms of the two primary quantities of interest in thermal design applications, namely the heat transfer rates and the tip temperature.

Ugur Akyol et al [28] to investigate the heat transfer and friction loss characteristics in a horizontal rectangular channel having attachments of hollow rectangular profile fins over one of its heated surface. The Reynolds number based on the flow averaged inlet velocity and the hydraulic diameter, ranged from 3000 to 32,000. The hollow rectangular profile fins in 10 cm height and $a \times b = 2 \text{ cm} \times 4 \text{ cm}$ dimensions with a thickness of 0.2 cm were mounted on a heating surface vertically. Reynolds number, fin arrangement and fin pitch in the flow direction were the experimental parameters. Both in-line and staggered fin arrangements were studied for one-fixed span wise ($S_x/a = 3$) and four different stream wise ($S_y/b = 1.5, 1.875, 2.5$ and 3.75) distances. Correlation equations for Nusselt number and thermal performances were determined for fin configurations and the straight channel case without fins.

III. CONCLUSION

From the literature survey following conclusions are made:-

1. The orientation and geometry of the fin plays vital role in enhancement of heat transfer rate in heat exchanger.
2. The heat transfer can be enhanced by improving the fluid to fin contact area. The efficiency of heat exchanger can be improved by increasing the contact surface area.
3. The space between the fins in array should be optimized for enhancing the heat transfer rate.
4. The thermal conductivity of the fin material and convective coefficient of fluid should be as better for enhancement of heat transfer.
5. The heat transfer rate increases with increase in fluid turbulence over the fin.
6. The heat transfer increases with increase in pressure drop across the channel of fluid flow over the fin.

REFERENCES

- [1] P. Singh, H. Lal, B. S. Ubhi, "Design and Analysis for Heat Transfer Through Fin with Extensions", International Journal of Innovative Research in Science, Engineering and Technology, Vol.3, Issue 5, May 2014.
- [2] Sachin R. Pawar, R. Yadav, "Computational Analysis of Heat Transfer by Natural Convection from Triangular Notched Fin Array", IJST-

- International Journal of Science Technology & Engineering, Vol-1, Issue 10, April 2015.
- [3] U. S. Gawai, Mathew V. K., Murtuza S. D., "Experimental Investigation Of Heat Transfer By Pin Fin", International Journal Of Engineering And Innovative Technology (IJEIT), Vol-2, Issue 7, January 2013.
 - [4] A. A. Walunj, D. D. Palande, "Experimental Analysis Of Inclined Narrow Plate- Fins Heat Sink Under Natural Convection", IPASJ International Journal Of Mechanical Engineering(IJME), Vol. 2, Issue- 6, June 2014.
 - [5] R. Hagote, S. K. Dahake, "Enhancement Of Natural Convection Heat Transfer Coefficient By Using V-Fin Array", International Journal Of Engineering Research And General Science, Vol-3, Issue-2, April 2015.
 - [6] V. Karthikeyan, R. Suresh Babu, G. Vignesh Kumar, "Design and Analysis of Natural Convective Heat Transfer Coefficient Comparison between Rectangular Fin Array with Perforated and Fin Arrays with Extension", International Journal of Science, Engineering and Technology Research (IJSETR), Vol-4, Issue-2, February 2015.
 - [7] M. Reddy, G. S. Shivanshankar, "Numerical Simulation of Forced Convection Heat Transfer Enhancement by Porous Pin Fins In Rectangular Channels", International Journal of Mechanical Engineering and Technology (IJMET), Vol-5, Issue-7, July 2014.
 - [8] M. Ehteshum, M. Ali, M. Tabassum, "Thermal and Hydraulic Performance Analysis of Rectangular Fin Arrays With Perforation Size and Number". 6th BSE International Conference On Thermal Engineering (ICTE 2014), Procedia Engineering
 - [9] K. Kumar, P. Vinay, R. Siddhardha, "Thermal and Structural Analysis of Tree Shaped Fin Array", Int. Journal of Engineering Research and Applications", Vol-3, Issue- 6, Dec 2013.
 - [10] V. Kumar, Dr. V. N. Bartaria, "CFD Analysis of an Elliptical Pin Fin Heat Sink Using Ansys Fluent V12.1", International Journal of Modern Engineering Research (IJMER), Vol-3, Issue 2, April 2013.
 - [11] K. Dhanawade, V. Sunnapwar, "Thermal Analysis of Square and Circular Perforated Fin Arrays by Forced Convection", International Journal of Current Engineering and Technology, Special Issue-2, February 2014.
 - [12] K. Chaitanya, G. V. Rao, "Transient Thermal Analysis Of Drop Shaped Pin Fin Array By Using CFD", International Journal Of Mechanical Engineering And Computer Applications, Vol-2, Issue 6, Dec 2014.
 - [13] R. Patil, H. M. Dange, "Experimental and Computational Fluid Dynamics Heat Transfer Analysis on Elliptical Fin by Forced Convection", International Journal of Engineering Research & Technology (IJERT), Vol-2, Issue-8, August 2013.
 - [14] Md. Abdul Reheem Junaidi, R. Rao, S. Sadaq, M. Ansari, Thermal Analysis Of Splayed Pin Fin Heat Sink, International Journal Of Modern Communication Technology & Research (IJMCTR), Vol-4, Issue-4, April 2014.
 - [15] Amol Dhumne, H. Farkade, Heat Transfer Analysis Of Cylindrical Perforated Fins In Staggered Arrangement, International Journal Of Innovative Technology And Exploring Engineering (IJITEE), Vol-2, Issue-5, April 2013.
 - [16] Mehran Ahmadi, Golnoosh Mostafavi, Majid Bahrami "Natural convection from rectangular interrupted fins". International Journal of Thermal Sciences.
 - [17] G. A. Ledezma, A. bejan "Optimal geometric arrangement of staggered vertical plates in natural convection" International Journal of Thermal Sciences.
 - [18] Shivdas S. Kharche, Hemant S. Farkade "Heat Transfer Analysis through Fin Array by Using Natural Convection", International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 4, April 2012)
 - [19] Wadhah Hussein Abdul Razzaq Al- Doori "Enhancement of natural convection heat transfer from rectangular fins by circular perforations" International Journal of Automotive and Mechanical Engineering (IJAME) ISSN: 2229-8648 (Print); ISSN: 2180-1606 (Online); Volume 4, pp. 428-436, July-December 2011.
 - [20] M.J. Sable1, S.J. Jagtap2 , P.S. Patil 3 , P.R. Baviskar4 & S.B. Barve5, "Experimental Investigation of Natural Convection from Heated Triangular Fin Array within a Rectangular Enclosure" International Review of Applied Engineering Research. ISSN 2248-9967 Volume 4, Number 3 (2014), pp. 203-210.
 - [21] Muhammad Najib Abdul Hamid, M.K. Abdullah, N.C. Ismail & Dr. Muhammad Abdul Mujeebu, "Optimum Tip Gap and Orientation of Multi-Piezofan for Heat Transfer Enhancement of Finned Heat Sink in Microelectronic Cooling" INTERNATIONAL JOURNAL OF HEAT AND MASS TRANSFER 55(21-22) · OCTOBER 2012
 - [22] M. Sasikumar & C. Balaji, "A Holistic Optimization of Convecting-Radiating Fin Systems", Journal of Heat Transfer, December, 2002 | Volume 124 | Issue 6
 - [23] B. Kundu and P. K. Das, "Optimum Profile of Thin Fins With Volumetric Heat Generation: A Unified Approach", J. Heat Transfer 127(8), 945-948 (Jan 18, 2005) (4 pages)doi:10.1115/1.1929784
 - [24] S. C. Haldar, "Laminar Free Convection Around a Horizontal Cylinder with External Longitudinal Fins", Heat Transfer Engineering Volume 25, Issue 6, 2004
 - [25] Dibakar Rakshit and C. Balaji, "Evaluation of candidate approaches in the study of conjugate convection from a fin array", International Communications in Heat and Mass Transfer, Volume 32, Issues 3-4, February 2005, Pages 529-538.

- [26] Wen-Lih Chen, , Yu-Ching Yang, Haw-Long Lee,
“Inverse problem in determining convection heat
transfer coefficient of an annular fin” Energy
Conversion and Management, Volume 48, Issue 4,
April 2007, Pages 1081–1088
- [27] Inmaculada Arauzo, Antonio Campo and Cristóbal
Cortés’ “Quick estimate of the heat transfer
characteristics of annular fins of hyperbolic profile
with the power series method”, Applied Thermal
Engineering Volume 25, Issue 4, March 2005,
Pages 623–634
- [28] Dinçer Akal, Kamil Kahveci, Ugur Akyol and
Ahmet Cihan’ “Drying kinetics of cotton based yarn
bobbins in a pressurized hot-air convective dryer”,
Proceedings of the Institution of Mechanical
Engineers, Part E: Journal of Process Mechanical
Engineering July 12, 2015 0954408915594725